

# Nitrogen Doping and Graphitization of Nanocrystalline Diamond Films for Enhanced Field Electron Emission

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Nitrogen-doped nanocrystalline diamond films were grown by d.c. arc plasma CVD on Si substrates from CH<sub>4</sub>/Ar/N<sub>2</sub>, CH<sub>4</sub>/H<sub>2</sub>/N<sub>2</sub>, and CH<sub>4</sub>/Ar/H<sub>2</sub>/N<sub>2</sub> gas mixtures. Different nitrogen content in the gas mixtures and different substrate temperatures were used to grow the films with different nitrogen content and microstructure. A nitrogen incorporation is promising for field electron emission from diamond films due to formation of electrical conductivity channels inside the films and changing the electron affinity on the film surface (n-doping and/or additional surface energy levels). In addition, higher growth temperature leads to partial graphitisation of the diamond films that can also improve the emission. So a set of the films with and without nitrogen was grown at high temperatures as well.

The film surface and microstructure was studied using AFM, SEM, Raman spectroscopy, X-ray Photoelectron Spectroscopy, Auger Electron Spectroscopy, and EELS to find correlations between the field emission and other film properties. The field electron emission was studied using both a macroscopic phosphor screen setup and a microprobe setup with tungsten probes of 10 µm in radius. Emission I-V dependences as well as emission sites distribution were measured and then analyzed depending on nitrogen and/or sp<sup>2</sup>-carbon content in the films.

It was found that nitrogenated nanocrystalline CVD diamond films show different microstructure than the films prepared without nitrogen, and the field electron emission for the nitrogenated films was typically better than for the films grown without nitrogen at the same the rest conditions. On the other hand, partially graphitized films grown at higher temperatures (with or without nitrogen in the gas mixtures) typically show the best field emission properties with emission threshold fields of as low as 1-1.5 V/µm, much higher density of emission sites, and higher working limit of the emission current. A competition of the nitrogen incorporation and graphitization for the field emission from the diamond films is discussed in dependence on the microstructure. Possible field emission mechanism are considered basing on the grain boundary effect.